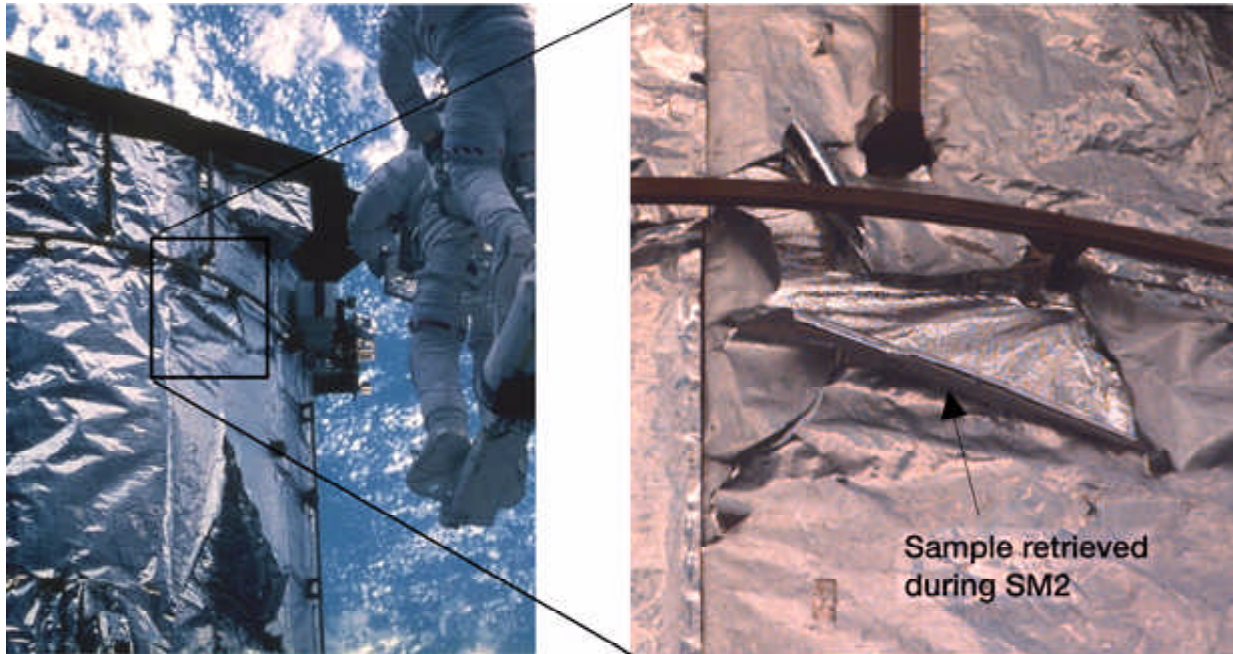


Thermal Contributions to the Degradation of Ground-Laboratory- and Space-Irradiated Teflon Investigated

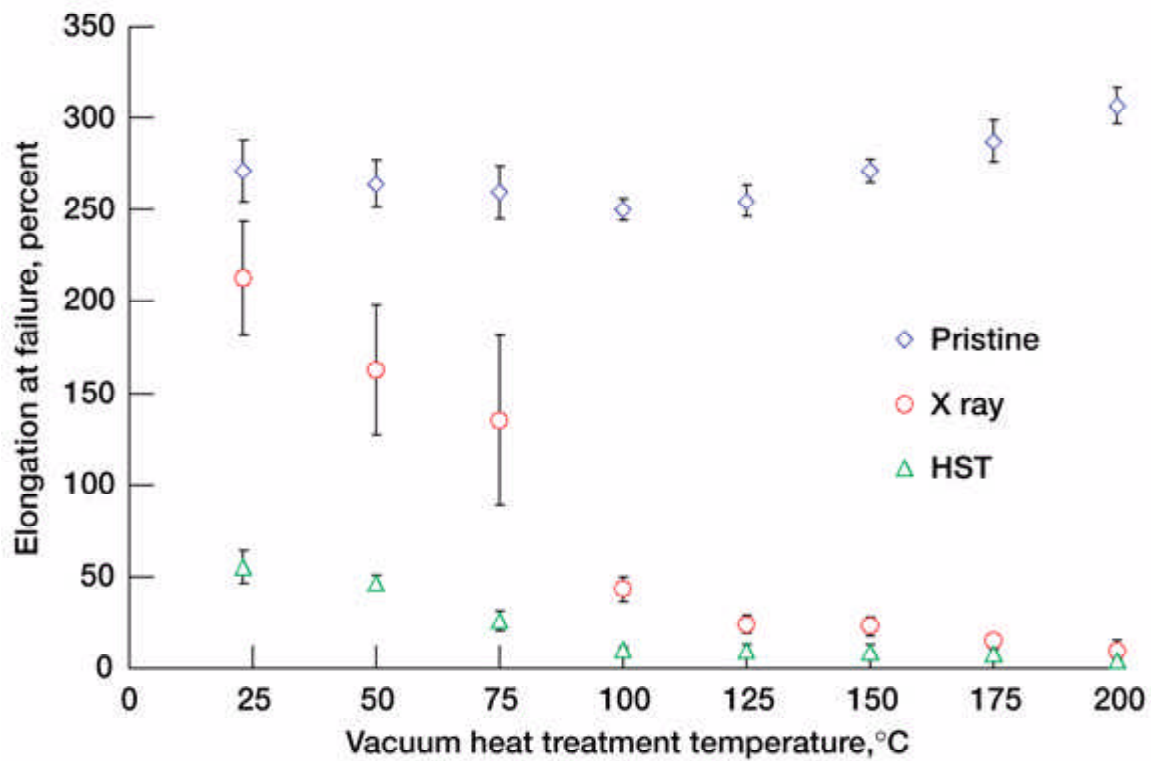


Multilayer insulation damage on the HST as witnessed during the second servicing mission. Left: Two cracked areas in the multilayer insulation outer layer, a large vertical crack and above it a tightly curled area. Right: Closeup of the tightly curled Al-FEP prior to retrieval.

The Hubble Space Telescope (HST) is covered with two primary types of thermal control materials, radiators and multilayer insulation blankets, which passively control temperatures during orbit. Both of these thermal control materials utilize back-surface metalized Teflon FEP (DuPont, fluorinated ethylene propylene) as the exterior (space-facing) layer because of its excellent optical properties (low solar absorptance and high thermal emittance). The aluminized-FEP (Al-FEP) outermost layer of the multilayer insulation blankets on the HST has become embrittled while in space, resulting in severe on-orbit cracking (see the photographs). During the second servicing mission, an extremely embrittled piece of Al-FEP was retrieved that had curled, exposing the back-surface aluminum to space (see the photograph on the right). Because the aluminum surface has a lower thermal emittance than the FEP, this curled piece reached 200 °C during orbit, 150 °C higher than the nominal temperature extreme. To better understand the effect of temperature on the rate of degradation, and on the mechanism of degradation, of this insulation material in the low-Earth-orbit environment, researchers at the NASA Glenn Research Center conducted experiments to determine the effect of heating on the degradation of FEP that has been irradiated in a ground laboratory facility or in space on

the HST. For this study, Teflon FEP retrieved from the HST during the third servicing mission after 9.7 years of space exposure was provided to Glenn by the NASA Goddard Space Flight Center.

Samples of pristine FEP were irradiated with 15.3-kV copper x rays. The x-ray exposure was not intended to simulate the full extent of damage occurring on Hubble, but to cause limited irradiation-induced polymer damage such that the additional degradation due to heating would be measurable. Samples of pristine, x-ray irradiated, and HST-retrieved FEP were heat treated from 50 to 200 °C at 25 °C intervals in a high-vacuum facility and evaluated for changes in tensile properties and density. The results indicate that although heating does not degrade the tensile properties of nonirradiated Teflon, there is a significant dependence on the degradation of the percent elongation at failure, and hence embrittlement, of irradiated Teflon as a function of heating temperature, with dramatic degradation occurring at 100 °C and higher exposures (see the graph). The density of nonheated irradiated FEP (ground or space irradiated) was found to be essentially the same as that of pristine FEP, although these samples are significantly embrittled. This indicates that irradiation induces scission in the polymer chains, resulting in embrittlement, but the polymer chain packing is not affected. Gradual increases in the density occurred with heating from 23 to 75 °C for all samples, with significant increases occurring at 100 °C and higher exposures. Larger increases occurred for the irradiated samples than for the pristine FEP. These results, which show that irradiated FEP experiences greater increases in density than pristine FEP for the same heat treatment, provide insight into the mechanisms of damage of the FEP. They indicate that irradiation causes bonds to break, which allows for greater mobility and crystallization upon heating than that which occurs with nonirradiated FEP. The tensile results and heated density data support chain scission as the primary mechanism of degradation of FEP in the space environment. The results show the significance of the on-orbit service temperature of FEP with respect to its degradation in the low-Earth-orbit space environment, which is important to understand when designing future spacecraft thermal systems.



Percent elongation at failure of pristine, ground laboratory x-ray-exposed FEP, and FEP retrieved from the HST as a function of vacuum heat-treatment temperature.

Find out more about the research of Glenn's Electro-Physics Branch--
<http://www.grc.nasa.gov/WWW/epbranch/>.

Glenn contact: Kim K. de Groh, 216-433-2297, Kim.K.deGroh@nasa.gov

Authors: Kim K. de Groh and Morgana Martin

Headquarters program office: OAT

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